Acta Polytechnica CTU Proceedings 1(1): 1–12, 2014 doi: 10.14311/APP.2014.01.0001

Old and New from Multifrequency Astrophysics

Franco Giovannelli[1], Lola Sabau-Graziati[2]

[1] *INAF - Istituto di Astrofisica e Planetologia Spaziali, Area di Ricerca di Tor Vergata, Via Fosso del Cavaliere, 100 - I00177 Roma, Italy*

[2] *INTA- Dpt. Cargas Utiles y Ciencias del Espacio, C/ra de Ajalvir, Km 4 - E28850 Torrejón de Ardoz, Madrid, Spain*

Corresponding author: franco.giovannelli@iaps.inaf.it

Abstract

In this short review paper we comment on some the most important steps that have been made in the past decades for a better understanding of the physics governing our Universe. The results we discuss come from the many ground-and-space-based experiments developed for measuring astrophysical sources in various energy bands. These experimental results are discussed within the framework of current theoretical models. Because of the limited length of this paper, we have selected only a few topics that, in our opinion, have been crucial for the progress of our understanding of the physics of cosmic sources.

Keywords: multifrequency astrophysics.

1 Introduction

With the advent of space-based experiments, it has been demonstrated that cosmic sources emit energy practically across the entire electromagnetic spectrum, albeit from different physical processes. Several observations stand as witness to these processes. Since the observed fluxes from cosmic sources can be highly variable in time and frequency, it follows that the physical processes from which they originate are in themselves highly variable. Therefore *simultaneous multifrequency observations* are strictly necessary in order to understand the actual behaviour of cosmic sources.

Indeed, space experiments have opened practically all of the electromagnetic "windows" on the Universe. A discussion of the most important results coming from multifrequency *photonic astrophysics* experiments will provide new inputs for the advance of our knowledge of physics, very often in the most extreme physical conditions.

We remark on the sheer magnitude of the high quality data across practically the whole electromagnetic spectrum that has become available to the scientific community since the beginning of the Space Era. With these data, we are attempting to explain the physics governing the Universe, and, moreover, its origin, which has been and still is a matter of the greatest curiosity for humanity.

We know for certain that the Universe has an absolute power limit $L_{\max} \sim \epsilon_{\rm pl}/t_{\rm pl} \sim c^5/G \sim 3.6 \times 10^{59}$ erg s^{-1}, where $\epsilon_{\rm pl}$ and $t_{\rm pl}$ are the Planck energy and Planck time, respectively, c the light velocity and G the gravitational constant. This amount of power is produced in different kind of cosmic sources, namely, the Early Universe (EU), Quasars (QSOs) and Active Galactic Nuclei (AGNs), Supernovae (SNe), Neutron Stars (NSs), and Black Holes (BHs), all types of Galaxies with their stars and Interstellar Medium (ISM), and Intergalactic Medium (IGM) (e.g., Lipunov, 1995). They radiate particles and photons at different levels of energy across the entire electromagnetic spectrum from their origins. However, the cosmic particle radiation arriving near Earth, with energies from $\sim 10^6$ to $\sim 10^{20}$ eV, is nearly isotropic, because of the galactic magnetic field, which cancels any particular directionality in the Galaxy. Such cosmic particle radiation apparently includes the nuclei of all known elements, as well as electrons, positrons, and antiprotons. So in spite of the cosmic rays being carriers of rich astrophysical information, it is very difficult to understand their message clearly. Indeed, although it is evident that they must originate in different sources, it is at the same time extremely difficult to separate the different contributions.

For more complete discussions, the reader can note the substantive books on this topic, containing excellent reviews, published by the Italian Physical Society (Giovannelli & Mannocchi, 1989, 1991, 1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011), by the Italian Astronomical Society (Giovannelli & Sabau-Graziati, 1996; 1999, 2002a, 2002b, 2010a, 2012a), by the Chinese Journal of Astronomy and Astrophysics (Giovannelli & Sabau-Graziati, 2003, 2006, 2008), and by Acta Polytechnica (Giovannelli & Mannocchi, 2013; Giovannelli & Sabau-Graziati, 2014).

With "passive" physics experiments (.i.e., observations) we view our Universe, while with active physics experiments we try to reproduce some of the physical conditions and processes occurring somewhere in the Universe. Both kinds of experiments converge to the knowledge of the physics governing the Universe.

In this paper we will discuss what seem to us some of the most relevant results obtained in the recent past that significantly improve our knowledge of the physics governing our universe. Deeper discussions about astroparticle physics can be found in the review papers by Giovannelli (2007, 2009, 2011, 2013). Giovannelli & Sabau-Graziati (2010b, 2012b), and De Angelis, Mansutti & Persic (2008) discussed in their review papers the multifrequency behaviour of high energy cosmic sources, and very high energy (VHE) γ-ray astrophysicsal sources.

1.1 Astroparticle physics development

The subject of High Energy Astrophysics is generally approached through the study of cosmic rays. The reason for this is historical in nature. Since the discovery of this extraterrestrial radiation by Victor Hess (1912), the scientific research involved in trying to discover the nature nature of these sources has been extensive. As a result, many separate research fields have been developed. Before particle accelerators came into operation, high energy cosmic rays were the laboratory tools for investigations of elementary particle production, and to date they are still the only source of particles with energies greater than 10^{12} eV. The research into the composition of the radiation led to the developing study of the astrophysical environment using the information in the charge, mass, and energy spectra; this field is also known as Particle Astrophysics.

Now, the Large Hadronic Collider (LHC), described by Straessner et al. (2011), is able to reach Tev energies for p-p interactions, and has attained energyies of 7 TeV, in order to search for the Higgs' Boson with the ATLAS Detector (Aad et al., 2012). No significant excess of events over the expected background is observed and limits on the Higgs boson production cross section are derived for a Higgs boson mass in the range 110 GeV $< m_H <$ 300 GeV. The observations exclude the presence of a standard model Higgs boson with a mass 145 $< m_H <$ 206 GeV at 95% confidence level.

Of great importance was the discovery of high energy photons near the top of the Earth's atmosphere. This originated the development of new astronomical fields such as the X-ray or γ-ray astronomy. But many of these high energy photons have their origin in the interactions of the high energy charged particles with cosmic matter, light, or magnetic fields. The particle astrophysics and the astronomical research fields have found in this fact a bond to join their efforts in trying to understand the high energy processes which occur in astrophysical systems.

A summary on the status of the search for the origin of the highest energy cosmic rays has been published by Biermann (1999). He mentioned several competing proposals, such as the supersymmetric particles. Biermann notes that Gamma Ray Bursts must also give rise to energetic protons, interacting high energy neutrinos and cosmological defects. In his paper, Biermann discussd the propagation of these particles, assuming that they are charged, and concluding that the distribution of arrival directions of the highest energy particles on the sky ought to reflect the source distribution as well as the propagation history. He remarked that the present status of our observations can be summarized as inconclusive. However, he concluded as follows: *If we can identify the origin of the events at the highest energies, beyond* 5×10^{19} eV*, the Greisen–Zatsepin–Kuzmin cut-off due to the microwave background, near to* 10^{21} *eV, and if we can establish the nature of their propagation through the universe to us, then we will obtain a tool to do physics at* EeV *energies.*

The arrival directions of ≥ 60 EeV ultra-high-energy cosmic rays (UHECRs) cluster along the supergalactic plane and correlate with active galactic nuclei (AGN) within $\approx$ 100 Mpc (Abraham et al., 2007, 2008). The association of several events with the nearby radio galaxy Cen A supports the paradigm that UHECRs are powered by supermassive black-hole engines and accelerated to ultra-high energies in the shocks formed by variable plasma winds in the inner jets of radio galaxies. The GZK horizon length of 75 EeV UHECR protons is $\approx$ 100 Mpc, so that the Auger results are consistent with an assumed proton composition of the UHECRs. In this scenario, the sources of UHECRs are FR II radio galaxies and FR I galaxies like Cen A with scattered radiation fields that enhance UHECR neutral–beam production. Radio galaxies with jets pointed away from us (i.e., more toward the plane of the sky) can still be observed as UHECR sources due to deflection of UHECRs by magnetic fields in the radio lobes of these galaxies. A broadband $\sim$ 1 MeV–10 EeV radiation component in the spectra of blazar AGN is formed by UHECR–induced cascade radiation in the extragalactic background light. This emission is too faint to be seen from Cen A, but could be detected from more luminous blazars (Dermer et al., 2009).

Recent evidence from the Pierre Auger Observatory suggests a transition, at 5 EeV-10EeV in the composition of Ultra High Energy Cosmic Rays (UHECRs), from protons to heavier nuclei such as iron (Abraham et al., 2010). Piran (2010) considered the implications of the heavier composition on the sources of UHECRs. He concluded that with typical reasonable parameters of a few nG for the extra–galactic magnetic field (EGMF) intensity and a coherence distance of a Mpc the distance that nuclei UHECR above the GZK energy traverses before photodisintegrating is only a few Mpc. In spite of the significantly weaker limits on the luminosity, Cen A is the only currently active potential source of nuclei UHECRs within this distance. The large deflections erases the directional anisotropy expected from a single source. If indeed the composition of above GZK–UHECRs is iron and if the EGMF is not too small then Cen A is the dominant source of observed nuclei UHECRs above the GZK limit.

In summary, charged cosmic rays are influenced in their propagation through space by the magnetic fields in the Galaxy, and for the lowest energy particles also in the solar system. The result is that the distribution of arrival directions as the radiation enters the Earth's atmosphere is nearly isotropic. It is not possible to identify the sources of the cosmic rays by detecting them. However, in the high energy interactions produced at the source, electrically neutral particles such as photons, neutrons, and neutrinos are also produced and their trajectories are not deviated, being directed from their point of origin to the observer. Owing to their short lifetime, neutrons cannot survive the path length to the Earth (decay length $\sim$ 9 pc at 1 PeV) and neutrinos do not interact efficiently in the atmosphere.

It is in this context that the Gamma Ray Astronomy has demonstrated itself to be a powerful tool. The observations made to date have detected γ-rays from many astronomical objects such as neutron stars, interstellar clouds, the center of our Galaxy and the nuclei of active galaxies (AGNs). One might expect very important implications for high energy astrophysics from the observations at energies greater than 10^{11} eV of extragalactic sources (e.g., Hillas & Johnson, 1990). The fluxes of γ-rays at these energies are attenuated because of their interactions with the cosmic radio, microwave, infrared and optical radiation fields. Measurements of the flux attenuation can then provide important information on the distribution of such fields. For instance, the threshold energy for pair production in reactions of photons with the 2.7 K background radiation is reached at 10^{14} eV and the absorption length is of the order of $\sim$ 7 kpc. For the infrared background the maximum absorption is reached at energies greater than 10^{12} eV.

The qualitative problem of the origin of cosmic rays is practically solved, while the quantitative problem in determining the fraction of them coming from the different possible sources is still open.

2 Very High Energy Sources

The most exciting results of the last decade have been obtained in the field of VHE astrophysics from different experiments (e.g. CGRO/EGRET, Wipple, HEGRA, CANGAROO, Celeste, Stacee, Tibet, HESS, VERITAS, MILAGRO, MAGIC) that detected many VHE cosmic sources.

The high energy sky. with the exception of Crab nebula, Vela X, and 3C 273, was empty until middle nineties. "Fast forward" to 19th April 2012, the VHE sky (E > 100 GeV) is populated by 107 cosmic sources: 46 out of 107 extragalactic and 61 galactic (http://www.mppmu.mpg.de/$\sim$rwagner/sources/ or http://tevcat.uchicago.edu).

One of the most interesting results has been the determination of the Spectral Energy Distribution (SED) of the Crab nebula, thanks to many measurements obtained by different HE–VHE experiments (Albert et al., 2008b).

Another exciting result has been the detection of the first variable galactic TeV source, namely the binary pulsar PSR B1259-63 (Aharonian et al., 2005). They found that the radio silence occurs during the time in which the pulsar is occulted by the excretion disk of the Be star.

The many detected sources, representing different galactic and extragalactic source populations, are supernova remnants (SNRs), pulsar wind nebulae (PWNe), giant molecular clouds (GMCs), star formation regions (SFRs), compact binary systems (CBSs), and active galactic nuclei (AGNs). Paredes & Persic (2010) reviewed the results from MAGIC Cherenkov telescope for most of the former class of sources. Models of TeV AGNs have been discussed by Lenain (2010).

3 Diffuse Extragalactic Background Radiation

After the Big Bang, the Universe started to expand with a fast cooling. The cosmic radiation observed now is probably an admixture of different components which had their origin in different stages of the evolution as the results of different processes. This is the Diffuse Extragalactic Background Radiation (DEBRA), which, if observed in different energy ranges, allows the study of many astrophysical, cosmological, and particle physics phenomena (Ressell & Turner, 1990. DEBRA is the witness of the whole history of the Universe from the Big Bang to present time.

Such history is marked by three main experimental witnesses supporting the Big Bang theory (e.g. Giovannelli & Sabau-Graziati, 2008): the light element abundances (Burles, Nollett & Turner, 2001); the CMBR temperature at various redshifts as determined by Srianand, Petitjean & Ledoux (2000), and the references therein; the CMB at z = 0 as result of COBE ($T_{CMBR}(0) = 2.726 \pm 0.010$ K), which is well fitted by a black body spectrum (Mather et al., 1994). At z$\simeq$ 2.34, the CMBR temperature is: 6.0 K < $T_{CMBR}(2.34)$ < 14.0 K. The prediction from the Hot Big Bang: $T_{CMBR} = T_{CMBR}(0) \times (1 + z)$ gives $T_{CMBR}(2.34) = 9.1$ K, which is consistent with the measurement (Srianand, Petitjean & Ledoux, 2000).

4 Reionization of the Universe

After the epoch of recombination (last scattering) between $\approx 3.8 \times 10^5 - \approx 2 \times 10^8$ yr ($z \approx 1000 - 20$), the universe experienced the so–called *Dark Ages*, where the dark matter halos collapsed and merged until the appearance of the first sources of light. This ended the Dark Ages. The ultraviolet light from the first sources of light also changed the physical state of the gas (hydrogen and helium) that fills the Universe from a neutral state to a nearly fully ionized one. This was the *Reionization Era* where the population III stars formed, and consequently, the first SNe and GRBs. This occurred between $\approx (2 - 5) \times 10^8$ yr ($z \approx 20 - 10$). Soon after population II stars started to form and probably the second wave of reionization occurred and stopped at $\approx 9 \times 10^8$ yr ($z \approx 6$) after the Big Bang, and then the evolution of galaxies started (e.g. Djorgovski, 2004, 2005). Quasars – the brightest and most distant objects known – offer a window on the reionization era, because neutral hydrogen gas absorbs their ultraviolet light.

Reionization drastically changes the environment for galaxy formation and evolution and in a hierarchical clustering scenario, the galaxies responsible for reionization may be the seeds of the most massive galaxies in the local Universe. Reionization is the last global phase transition in the Universe. The reionization era is thus a cosmological milestone, marking the appearance of the first stars, galaxies and quasars.

Recent results obtained by Ouchi et al. (2010) give an important contribution for solving such a problem. Indeed, from the the Lyα luminosity function (LF), clustering measurements, and Lyα line profiles based on the largest sample to date of 207 Lyα emitters at z = 6.6 on the 1 deg^2 sky of Subaru/XMM-Newton Deep Survey field, Ouchi et al. (2010) found that the combination of various reionization models and observational results about the LF, clustering, and line profile indicates that there would exist a small decrease of the intergalactic medium's (IGM's) Lyα transmission owing to reionization, but that the hydrogen IGM is not highly neutral at z = 6.6. Their neutral-hydrogen fraction constraint implies that the major reionization process took place at z $>\sim$ 7.

The W. M. Keck 10-m telescope has shown the quasar SDSS J1148+5251 at a redshift of 6.41 ($\approx 12.6 \times 10^9$ yr ago). This is currently the most distant quasar known (Djorkovski, 2004). This measurement does not contradict the result found for the epoch of reionization. However, the search of the epoch of reionization is still one of the most important open problems for understanding the formation of the first stars, galaxies and quasars.

5 Clusters of Galaxies

The problems of the production and transport of heavy elements seems to have been resolved. Indeed, thermally driven galactic winds, such as from M82, have shown that only active galaxies with an ongoing starburst can enrich the ICM with metals. The amounts of metals in the ICM is at least as high as the sum of the metals in all galaxies of the cluster (e.g. Tozzi et al., 2003). Several clusters of galaxies, having strong radio emission, have been associated with EGRET sources. This is an important step in clarifying the nature of many unknown EGRET sources (Colafrancesco, 2002). However, in the first 11 months of operations of the Fermi LAT monitoring program of CGs no γ-ray emission from any of the monitored CGs has been detected (Ackermann et al., 2010b).

In spite of many important results coming from satellites of the last decade, the hierarchical distribution of the dark matter, and the role of the intergalactic magnetic fields in CGs are still open. Simultaneous multifrequency measurements with higher sensitivity instruments, in particular those in hard X-ray and radio energy regions and optical-to-near infrared (NIR) could solve such problems.

6 Dark Energy and Dark Matter

By using different methods to determine the mass of galaxies it has been found a discrepancy that suggests $\sim 95\%$ of the universe is in a form that cannot be seen. This form of unknown content of the universe is the sum of *Dark Energy (DE)* and *Dark Matter (DM)*. Colafrancesco (2003) deeply discussed about *New Cosmology*.

The discovery of the nature of the dark energy may provide an invaluable clue for understanding the nature and the dynamics of our universe. However, there is $\sim 30\%$ of the matter content of the universe which is dark and still requires a detailed explanation. Baryonic DM consisting of MACHOs (Massive Astrophysical Compact Halo Objects) can yield only some fraction of the total amount of Dark Matter required by CMB observations. WIMPs (Weakly Interacting Massive Particles) (non-baryonic DM) can yield the needed cosmological amount of DM and its large scale distribution provided that it is "cold" enough. Several options have been proposed so far like: *i)* light neutrinos with mass in the range $m_\nu \sim 10-30$ eV, *ii)* light exotic particles like axions with mass in the range $m_{axion} \sim 10^{-5} - 10^{-2}$ eV or weakly interacting massive particles like neutralinos with mass in the range $M_\chi \sim 10-1000$ GeV, this last option being favored at present (see, e.g., Ellis 2002).

EROS and MACHO, two experiments based on the gravitational microlensing, were developed. Two lines of sight have been probed intensively: the Large (LMC) and the Small (SMC) Magellanic Clouds, located 52 kpc and 63 kpc respectively from the Sun (Palanque-Delabrouille, 2003).

With 6 years of data towards the LMC, the MACHO experiment published a most probable halo fraction between 8 and 50% in the form of 0.2 $M_\odot$ objects (Alcock et al., 2000). Most of this range is excluded by the EROS exclusion limit, and in particular the MACHO preferred value of 20% of the halo.

Among experiments for searching WIMPs as dark matter candidates, there is PAMELA, an experiment devoted to a search for dark matter annihilation, antihelium (primordial antimatter), new matter in the Universe (strangelets?), the study of cosmic-ray propagation (light nuclei and isotopes), electron spectrum (local sources?), solar physics and solar modulation, and terrestrial magnetosphere. A comparison of the expected PAMELA results with many other experiments has been discussed by Morselli (2007). Bruno (2011) discussed some results from PAMELA.

The search for DM is one of the main open problems of today's astroparticle physics.

7 The Galactic Center

The Galactic Center (GC) is one of the most interesting places for testing theories in which frontier physics plays a fundamental role. There is an excellent review of Mezger, Duschl & Zylka (1996), which discusses the physical state of stars and interstellar matter in the Galactic Bulge ($R \sim 0.3$–3 kpc from the dynamic center of the Galaxy), in the Nuclear Bulge ($R < 0.3$ kpc) and in the Sgr A Radio and GMC Complex (the central ~ 50 pc of the Milky Way). This review reports also a list of review papers and conference proceedings related to the Galactic Center with bibliographic details. In the review paper by Giovannelli & Sabau-Graziati (2004, and the references therein) the multifrequency behaviour of the Galactic Center has been also discussed.

LaRosa et al. (2000) presented a wide-field, high dynamic range, high-resolution, long-wavelength ($\lambda = 90$ cm) VLA image of the Galactic center region. This is the most accurate image of the GC. While highly obscured in optical and soft X-rays; it shows a central compact object (a black hole candidate) with M $\sim 3.6 \times 10^6$ $M_\odot$ (Genzel et al., 2003a), which coincides with the compact radio source Sgr A* [R.A. 17 45 41.3 (hh mm ss); Dec.: -29 00 22 (dd mm ss)]. Sgr A* in X-rays/infrared is highly variable (Genzel et al., 2003b).

The GC is also a good candidate for indirect dark matter observations. Moreover, the detected excess of HE γ-rays at GC would be produced by neutralino annihilation in the dark matter halo. Such an excess could be better measured by the FERMI observatory.

8 Gamma-Ray Bursts

The many theoretical descriptions of gamma-ray bursts (GRBs) show that the origin of these sources is still an open and strongly controversial topic. Fireball (FB) model (Meszaros & Rees, 1992; Piran, 1999), cannon ball (CB) model (Dar & De Rújula, 2004), spinnin-precessing jet (SPJ) model (Fargion, 2003a,b; Fargion & Grossi, 2006), fireshell (Izzo et al., 2010) model — directly coming from electromagnetic black hole (EMBH) model (e.g. Ruffini et al. 2003 and the references therein) — are the most popular, but each one against the others.

Important implications on the origin of the highest redshift GRBs are coming from the detection of the GRB 080913 at z =6.7 (Greiner et al., 2009), GRB 090423 at z $\sim$ 8.2 (Tanvir et al., 2009), and GRB 090429B (Cucchiara et al., 2011). This means that really we are approaching to the possibility of detecting GRBs at the end of Dark Era, where the first Pop III stars appeared. Izzo et al. (2010) discussed successfully a theoretical interpretation of the GRB 090423 within their fireshell model.

Wang & Dai (2009) studied the high-redshift star formation rate (SFR) up to z $\simeq$ 8.3 considering the Swift GRBs tracing the star formation history and the cosmic metallicity evolution in different background cosmological models including ΛCDM, quintessence, quintessence with a time-varying equation of state and brane-world models. ΛCDM model is the preferred which is however compared with other results.

Although great progress has been obtained in the last few years, GRBs theory needs further investigation in the light of the experimental data coming from old and new satellites, often coordinated, such as BeppoSAX or BATSE/RXTE or ASM/RXTE or IPN or HETE or INTEGRAL or SWIFT or AGILE or FERMI or MAXI.

9 Extragalactic Background Light

Space is filled with diffuse extragalactic background light (EBL) which is the sum of starlight emitted by galaxies through the history of the universe. High energy γ-rays traversing cosmological distances are expected to be absorbed through their interactions with the EBL by: $\gamma_{VHE} + \gamma_{EBL} \longrightarrow e^+ e^-$. Then the γ-ray flux Φ is suppressed while travelling from the emission point to the detection point, as $\Phi = \Phi_0 e^{-\tau(E,z)}$, where τ(E,z) is the opacity. The e–fold reduction [τ(E,z) = 1] is the Gamma Ray Horizon (GRH) (e.g. Blanch & Martinez, 2005; Martinez, 2007).

The direct measurement of the EBL is difficult at optical to infrared wavelengths because of the strong foreground radiation originating in the solar system. However, the measurement of the EBL is important for VHE gamma-ray astronomy, as well as for astronomers modelling star formation and galaxy evolution. Second only in intensity to the cosmic microwave background (CMB), the optical and infrared (IR) EBL contains the imprint of galaxy evolution since the Big Bang. This includes the light produced during formation and reprocessing of stars. Current measurements of the EBL are reported in the paper by Schroedter (2005, and references therein). He used the available VHE spectra from six blazars. More recently, the redshift region over which the gamma reaction history (GRH) can be constrained by observations has been extended up to z = 0.536. Upper EBL limit based on 3C 279 data have been obtained (Albert et al., 2008a). The universe is more transparent to VHE gamma rays than expected. Thus many more AGNs could be seen at these energies.

Indeed, Abdo et al. (2009a) observed a number of TeV-selected AGNs during the first 5.5 months of observations with the Large Area Telescope (LAT) on–board the Fermi Gamma-ray Space Telescope. Redshift–dependent evolution is detected in the spectra of objects detected at GeV and TeV energies. The most reasonable explanation for this is absorption on the EBL, and as such, it would represent the first model–independent evidence for absorption of γ-rays on the EBL. Abdo et al. (2010b) by using a sample of γ-ray blazars with redshift up to z $\sim$ 3, and GRBs with redshift up to z $\sim$ 4.3, measured by Fermi/LAT placed upper limits on the γ-ray opacity of the universe at various energies and redshifts and compared this with predictions from well–known EBL models. They found that an EBL intensity in the optical-ultraviolet wavelengths as great as predicted by the "baseline" model of Stecker, Malkan & Scully (2006) that can be ruled out with high confidence.

10 Relativistic Jets

Relativistic jets have been found in numerous galactic and extragalactic cosmic sources at different energy bands. The emitted spectra of jets from cosmic sources of different nature are strongly dependent on the angle formed by the beam axis and the line of sight, and obviously by the Lorentz factor of the particles (e.g. Bednarek et al., 1990 and the references therein; Beall, Guillory & Rose, 1999, 2009; Beall, 2002, 2003, 2008, 2009; Beall et al., 2006, 2007). So, observations of jet sources at different frequencies can provide new inputs for the comprehension of such extremely efficient carriers of energy, like for the cosmological GRBs. The discovered analogy among μ–QSOs, QSOs, and GRBs is fundamental for studying the common physics governing these different classes of objects via μ–QSOs, which are galactic, and then apparently brighter and with all processes occurring in time scales accessible by our experiments (e.g. Chaty, 1998). Chaty (2007) remarked the importance of multifrequency observations of jet sources by means of the measurements of GRS 1915+105.

Dermer et al. (2009) suggest that ultra-high energy cosmic rays (UHECRs) could come from black hole jets of radio galaxies. Spectral signatures associated with UHECR hadron acceleration in studies of radio galaxies and blazars with FERMI observatory and ground–based γ-ray observatories can provide evidence for cosmic-ray particle acceleration in black hole plasma jets. Also in this case, γ-ray multifrequency observations (MeV–GeV–TeV) together with observations of PeV neutrinos could confirm whether black-hole jets in radio galaxies accelerate the UHECRs.

Despite their frequent outburst activity, microquasars have never been unambiguously detected emitting high-energy gamma rays. The Fermi/LAT has detected a variable high-energy source coinciding with the position of the X-ray binary and microquasar Cygnus X-3. Its identification with Cygnus X-3 is secured by the detection of its orbital period in gamma rays, as well as the correlation of the LAT flux with radio emission from the relativistic jets of Cygnus X-3. The γ-ray emission probably originates from within the binary system (Abdo et al., 2009b). Also the microquasar LS 5039 has been unambiguously detected by Fermi/LAT being its emission modulated with a period of 3.9 days. Analyzing the spectrum, variable with the orbital phase, and having a cutoff, Abdo et al. (2009c) conclude that the γ-ray emission of LS 5039 is magnetospheric in origin, like that of pulsars detected by Fermi. This experimental evidence of emission in the GeV region from microquasars opens an interesting window about the formation of relativistic jets.

11 Cataclysmic Variables

The detection of CVs with the INTEGRAL observatory (Barlow et al., 2006) have recently renewed the interest of high energy astrophysicists for such systems, and subsequently involving once more the low–energy astrophysical community. The detection of CVs having orbital periods inside the so-called *Period Gap* between 2 and 3 hours, which separates polars (apparently generating gravitational radiation) from intermediate polars (which suffer magnetic braking) renders attractive the idea of the physical continuity between these two classes. Further investigations are necessary for solving this important problem.

For a recent review on CVs see the paper by Giovannelli & Sabau-Graziati (2012c).

12 High Mass X-Ray Binaries

For general reviews see e.g. Giovannelli & Sabau-Graziati (2001, 2004) and van den Heuvel (2009) and references therein.

HMXBs are young systems, with age $\leq 10^7$ yr, mainly located in the galactic plane (e.g., van Paradijs, 1998). A compact object — the secondary star —, mostly a magnetized neutron star (X-ray pulsar) is orbiting around an early type star (O, B, Be) — the primary — with $M \geq 10$ $M_\odot$. The optical luminosity of the system is dominated by the early type star.

Such systems are the best laboratory for the study of accreting processes, thanks to their relatively high luminosity in a large part of the electromagnetic spectrum. Because of the strong interactions between the optical companion and collapsed object, low and high energy processes are strictly related.

In X-ray/Be binaries the mass loss processes are due to the rapid rotation of the Be star, the stellar wind and, sporadically, to the expulsion of casual quantity of matter essentially triggered by gravitational effects close to the periastron passage of the neutron star. The long orbital period (> 10 days) and a large eccentricity of the orbit (> 0.2) together with transient hard X-ray behavior are the main characteristics of these systems. Among the whole sample of galactic systems containing 114 X-ray pulsars (Johnstone, 2005), only few of them have been extensively studied. Among these, the system A 0535+26/HDE 245770 is the best known thanks to concomitant favorable causes, which rendered possible thirty eight years of coordinated multifrequency observations, most of them discussed by e.g. Giovannelli & Sabau-Graziati (1992, 2008), Burger et al. (1996).

Accretion powered X-ray pulsars usually capture material from the optical companion via stellar wind, since this primary star generally does not fill its Roche lobe. However, in some specific conditions (e.g. the passage at the periastron of the neutron star) and in particular systems (e.g. A 0535+26/HDE 245770), it is possible the formation of a temporary accretion disk around the neutron star behind the shock front of the stellar wind. This enhances the efficiency of the process of mass transfer from the primary star onto the secondary collapsed star, as discussed by Giovannelli & Ziolkowski (1990) and by Giovannelli et al. (2007) in the case of A 0535+26.

Giovannelli & Sabau-Graziati (2011) discussed the history of the discovery of optical indicators of high energy emission in the prototype system A0535+26/HDE 245770 ≡ Flavia' star, updated to the March–April 2010 event when a strong optical activity occurred roughly 8 days before the X-ray outburst (Caballero et al., 2010) that was predicted by Giovannelli, Gualandi & Sabau-Graziati (2010). This event together with others occurred in the past allowed to Giovannelli & Sabau-Graziati (2011) to conclude that X-ray outbursts occur ~ 8 days after the periastron passage. Giovannelli, Bisnovatyi-Kogan & Klepnev (2013) developed a model for explaining such a delay by the time of radial motion of the matter in a non–stationary accretion disk around the neutron star, after an increase of the mass flux in the vicinity of a periastral point in the binary. This time is determined by the turbulent viscosity, with the parameter $\alpha = 0.1 - 0.3$.

However how X-ray outbursts are triggered in X-ray pulsars constitute one important still open problem giving rise to controversy within astrophysicists.

Important news are coming also from GeV observations of HMXBs. Indeed, Abdo et al. (2009e) present the first results from the observations of LSI + 61°303 using Fermi/LAT data obtained between 2008 August and 2009 March. Their results indicate variability that is consistent with the binary period, with the emission being modulated at 26.6 days. This constitutes the first detection of orbital periodicity in high–energy γ-rays (20 MeV-100 GeV). The light curve is characterized by a broad peak after periastron, as well as a smaller peak just before apastron. The spectrum is best represented by a power law with an exponential cutoff, yielding an overall flux above 100 MeV of $\simeq 0.82 \times 10^{-6}$ ph cm^{-2} s^{-1}, with a cutoff at ~ 6.3 GeV and photon index $\gamma \sim 2.21$. There is no significant spectral change with orbital phase. The phase of maximum emission, close to periastron, hints at inverse Compton scattering as the main radiation mechanism. However, previous very high-energy gamma ray (> 100 GeV) obser vations by MAGIC and VERITAS show peak emission close to apastron. This and the energy cutoff seen with Fermi suggest that the link between HE and VHE gamma rays is nontrivial. This is one open problem to be solved in future.

12.1 Obscured sources and supergiant fast X-ray transients

Relevant are INTEGRAL results about a new population of obscured sources and Supergiant Fast X-ray Transients (SFXTs) (Chaty & Filliatre, 2005; Chaty, 2007; Rahoui et al., 2008; Chaty, 2008). The importance of the discovery of this new population is based on the constraints on the formation and evolution of HMXBs: does dominant population of short-living systems – born with two very massive components – occur in rich star-forming region? What will happen when the supergiant star dies? Are primary progenitors of NS/NS or NS/BH mergers good candidates of gravitational waves emitters? Can we find a link with short/hard γ-ray bursts?

13 Ultra–Compact Double–Degenerated Binaries

Ultra-compact, double-degenerated binaries (UCD) consist of two compact stars, which can be black holes, neutron stars or white dwarfs. In the case of two white dwarfs revolving around each other with an orbital period $P_{orb} \leq 20$ min. The separation of the two components for a UCD with $P_{orb} \approx 10$ min or shorter is smaller than Jupiter's diameter.

These UCD are evolutionary remnants of low–mass binaries, and they are numerous in the Milky Way. The discovery of UCD is foreboding interesting hints for gravitational–wave possible detection with LISA observatory.

14 Magnetars

The discovery of magnetars (Anomalous X-ray Pulsars – AXPs – and Soft Gamma-ray Repeaters – SGRs) is also one of the most exciting results of the last years (Mereghetti & Stella, 1995; van Paradijs, Taam & van den Heuvel, 1995; and e.g. review by Giovannelli & Sabau-Graziati, 2004 and the references therein). Indeed, with the magnetic field intensity of order $10^{14} - 10^{15}$ G a question naturally arises: what kind of SN produces such AXPs and SGRs? Are really the collapsed objects in AXPs and SGRs neutron stars? (e.g. Hurley, 2008). With such high magnetic field intensity an almost 'obvious' consequence can be derived: the correspondent dimension of the source must be of ~ 10 m (Giovannelli & Sabau-Graziati, 2006). This could be the dimension of the acceleration zone in supercompact stars. Could they be quark stars?

Ghosh (2009) discussed some of the recent developments in the quark star physics along with the consequences of possible hadron to quark phase transition at high density scenario of neutron stars and their implications on the Astroparticle Physics.

Important consequences could be derived by considering the continuity among rotation-powered pulsars, magnetars, and millisecond pulsars. Such continuity has been experimentally demonstrated (Kuiper, 2007). However, the physics underlying that observational continuity is not yet clear.

15 Neutrino Astronomy

For a short discussion about neutrino astronomy, see for instance the paper by Giovannelli (2007 and the references therein), as well as all the papers of the Session *Neutrino Astronomy*, which appeared in the proceedings of the Vulcano Workshops 2006, 2008, and 2010 (Giovannelli & Mannocchi, 2007, 2009, 2011).

However, it is important to remark that several papers have appeared about: i) the sources of HE neutrinos (Aharonian, 2007) and diffuse neutrinos in the Galaxy (Evoli, Grasso & Maccione, 2007); ii) Potential neutrino signals from galactic γ-ray sources (Kappes et al., 2007); iii) galactic cosmic-ray pevatrons with multi-TeV γ-rays and neutrinos (Gabici & Aharonian, 2007); iv) results achieved with AMANDA: 32 galactic and extragalactic sources have been detected (Xu & the ICECube Collaboration, 2008); diffuse neutrino flux from the inner Galaxy (Taylor et al., 2008); discussion about VHE neutrino astronomic experiments (Cao, 2008). Important news and references can be found in the proceedings of the *Les Rencontres de Physique de la Vallée d'Aoste* (Greco, 2009, 2010).

News about the neutrino oscillations have been reported by Mezzetto (2011). The angle Θ_{13} is different than zero: $\sin^2 \Theta_{13} = 0.013$. This result opens the door to CP violation searches in the neutrino sector, with profound implications for our understanding of the matter–antimatter asymmetry in the universe.

16 Conclusions and Reflections

It is becoming increasingly clear that the energy régime covered by VHE γ-ray astronomy will be able to address a number of significant scientific questions, which include: i) What parameters determine the cut-off energy for pulsed γ-rays from pulsars? ii) What is the role of shell-type supernovae in the production of cosmic rays? iii) At what energies do AGN blazar spectra cut-off? iv) Are gamma blazar spectral cut-offs intrinsic to the source or due to intergalactic absorption? v) Is the dominant particle species in AGN jets leptonic or hadronic? vi) Can intergalactic absorption of the VHE emission of AGN's be a tool to calibrate the epoch of galaxy formation, the Hubble parameter, and the distance to γ-ray bursts? vii) Are there sources of γ-rays which are 'loud' at VHEs, but 'quiet' at other wavelengths?

It appears evident the importance of Multifrequency Astrophysics. There are many problems in performing simultaneous Multifrequency, Multienergy Multisite, Multiinstrument, Multiplatform measurements due to: i) objective technological difficulties; ii) sharing common scientific objectives; iii) problems of scheduling and budgets; iv) politic management of science.

In spite of the many ground-based and space-based experiments providing an impressive quantity of excellent data in different energy regions, many open problems still exist. We believe that only by drastically changing the philosophy of the experiments will it be possible to solve most of the present open problems. For instance, in the case of space–based experiments, small satellites, dedicated to specific missions and problems, and having the possibility of scheduling very long time observations, must be supported because of their relative faster preparation, easier management and lower costs with respect to medium and large satellites.

We strongly believe that in the next decades "passive" physics experiments in space, as well as ground-based, and perhaps Lunar-based observatories will be the most suitable probes in sounding the physics of the Universe. Probably the active physics experiments have already reached the maximum dimensions compatible with a reasonable cost/benefit ratio, with the obvious exception of the neutrino astronomy experiments.

Acknowledgement

We wish to thank the SOC of the Karlovy Vary 10th INTEGRAL/BART Workshop for inviting us to discuss this review during the workshop, and the LOC for logistical support for one of us (FG). This research has made use of NASA's Astrophysics Data System.

References

[1] Aad, G. et al. (ATLAS Collaboration): 2012, Phys. Rev. Letter 108, 1802.

[2] Abdo, A.A. et al.: 2009a, ApJ 707, 1310.

[3] Abdo, A.A. et al.: 2009b, Sci. 326, 1512.

[4] Abdo, A.A. et al.: 2009c, ApJ 706, L56.

[5] Abdo, A.A. et al.: 2009e, ApJ 701L, 123.

[6] Abdo, A.A. et al.: 2010b, ApJ 723, 1082.

[7] Abraham, J. et al. (The Pierre Auger Collaboration): 2007, Science 318, 938.

[8] Abraham, J. et al. (The Pierre Auger Collaboration): 2008, Astropart. Phys. 29, 188. doi:10.1016/j.astropartphys.2008.01.002

[9] J. Abraham, J. et al.: 2010, Phys. Rev. Letter 104, 091101. doi:10.1103/PhysRevLett.104.091101

[10] Ackermann, M. et al.: 2010b, ApJ 717, L71. doi:10.1088/2041-8205/717/1/L71

[11] Aharonian, F.A.: 2007, Sci. 315, 70. doi:10.1126/science.1136395

[12] Aharonian, F. et al.: 2005, A&A 442, 1.

[13] Albert, J. et al. (MAGIC Collaboration): 2008a, Sci. 320, 1752. doi:10.1126/science.1157087

[14] Albert, J. et al.: 2008b, ApJ 674, 1037. doi:10.1086/525270

[15] Alcock, C. et al.: 2000, ApJ 542, 281. doi:10.1086/309512

[16] Barlow, E.J. et al.: 2006, MNRAS 372, 224. doi:10.1111/j.1365-2966.2006.10836.x

[17] Beall, J.H.: 2002, in *Multifrequency Behaviour of High Energy Cosmic Sources*, F. Giovannelli & L. Sabau-Graziati (eds.), Mem. SAIt 73, 379.

[18] Beall, J.H.: 2003, ChJA&AS 3, 373.

[19] Beall, J.H.: 2008, ChJA&AS 8, 311.

[20] Beall, J.H.: 2009, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi, (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 98, 283.

[21] Beall, J.H., Guillory, J., Rose, D.V.: 1999, in *Multifrequency Behaviour of High Energy Cosmic Sources*, F. Giovannelli & L. Sabau-Graziati (eds.), Mem. SAIt 70, 1235.

[22] Beall, J.H. et al.: 2006, ChJA&AS1 6, 283.

[23] Beall, J.H. et al.: 2007, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi, (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 93, 315.

[24] Beall, J.H., Guillory, J., Rose, D.V.: 2009, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi, (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 98, 301.

[25] Bednarek, W., Giovannelli, F., Karakula, S., Tkaczyk, W.: 1990, A&A 236, 268.

[26] Biermann, P. L.: 1999, Astrophys. and Space Sci. 264, 423.

[27] Blanch, O., Martinez, M.: 2005, Astrop. Phys. 23, 588.

[28] Bruno, A.: 2011, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 103, 139.

[29] Burger, M. et al.: 1996, in *Multifrequency Behaviour of High Energy Cosmic Sources*, F. Giovannelli & L. Sabau-Graziati (eds.), Mem. SAIt 67, 365.

[30] Burles, S., Nollet, K.M., Turner, M.S.: 2001, ApJL 552, L1.

[31] Caballero, I. et al.: 2010, ATEL No. 2541.

[32] Cao, Z.: 2008, Nucl. Phys. B (Proc. Suppl.) 175-176, 377.

[33] Chaty, S.: 1998, Ph.D. thesis, University Paris XI.

[34] Chaty, S., 2007, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 93, 329.

[35] Chaty, S.: 2008, ChJA&AS 8, 197.

[36] Chaty, S., Filliarte, P.: 2005, ChJA&AS 5, 104.

[37] Colafrancesco, S.: 2002, A&A 396, 31.

[38] Colafrancesco, S.: 2003, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 85, 141.

[39] Cucchiara, A. et al.: 2011, ApJ 736, 7.

[40] Dar, A., De Rújula, A.: 2004, Phys. Rep. 405, 203.

[41] De Angelis, A., Mansutti, O., Persic, M.: 2008, Il N. Cim. 31 N. 4, 187.

[42] Dermer,C.D., Razzaque, S., Finke, J.D., Atoyan, A.: 2009, New J. of Phys. 11, 1. doi:10.1088/1367-2630/11/6/065016

[43] Djorgovski, S.G.: 2004, Nature 427, 790. doi:10.1038/427790a

[44] Djorgovski, S.G.: 2005, in *The Tenth Marcel Grossmann Meeting*, M. Novello, S. Perez Bergliaffa & R. Ruffini (eds.), World Scientific Publishing Co., p. 422.

[45] Ellis, J.: 2002, astro-ph 4059 (arXiv:hep-ex/0210052).

[46] Evoli, C., Grasso, D., Maccione, L.: 2007, astro-ph 0701856.

[47] Fargion, D.: 2003a, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy 85, 267.

[48] Fargion, D.: 2003b, ChJA&AS 3, 472.

[49] Fargion, D., Grossi, M.: 2006, ChJA&AS1 6, 342.

[50] Gabici, S., Aharonian, F.A.: 2007, ApJL 665, L131. doi:10.1086/521047

[51] Genzel, R. et al.: 2003a, ApJ 594, 812. doi:10.1086/377127

[52] Genzel, R. et al.: 2003b, Nature 425, 934. doi:10.1038/nature02065

[53] Ghosh, S.K.: 2009, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi, (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 98, 243.

[54] Giovannelli, F.: 2007, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 93, 3.

[55] Giovannelli, F.: 2009, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 98, 3.

[56] Giovannelli, F.: 2011, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 103, 3.

[57] Giovannelli, F., Ziółkowski, J.: 1990, AcA 40, 95.

[58] Giovannelli, F., Sabau-Graziati, L.: 1992, Space Sci. Rev. 59, 1.

[59] Giovannelli, F., Sabau-Graziati, L.: 2001, Ap&SS 276, 67. doi:10.1023/A:1011607814902

[60] Giovannelli, F., Sabau-Graziati, L.: 2004, Space Sci. Rev. 112, 1. doi:10.1023/B:SPAC.0000032807.99883.09

[61] Giovannelli, F., Sabau-Graziati, L.: 2006, ChJA&AS1 6, 1.

[62] Giovannelli, F., Bernabei, S., Rossi, C., Sabau-Graziati, L.: 2007, A&A 475, 651.

[63] Giovannelli, F., Mannocchi, G. (eds.): 1989, 1991, 1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, Proc. Vulcano Workshops on *Frontier Objects in Astrophysics and Particle Physics*, Italian Physical Society, Ed. Compositori, Bologna, Italy, Volumes 19, 28,40, 47, 57, 65, 73, 85, 90, 93, 98, 103.

[64] Giovannelli, F., Mannocchi, G. (eds.): 2013, Proc. Vulcano Workshops on *Frontier Objects in Astrophysics and Particle Physics*, Acta Polytechnica (in press).

[65] Giovannelli, F., Sabau-Graziati, L. (eds.): 1996, 1999, 2002a, 2002b, 2010a, 2012a, Proc. Frascati Workshops on *Multifrequency Behaviour of High Energy Cosmic Sources*, Mem. SAIt. Volumes 67, 70, 73 N. 1, 73 N. 4, 81 N. 1, 83 N. 1.

[66] Giovannelli, F., Sabau-Graziati, L. (eds.): 2003, 2006, 2008, Proc. Frascati Workshops on *Multifrequency Behaviour of High Energy Cosmic Sources*, ChJA&A Volumes 3 Suppl., 6 Suppl., 8 Suppl.

[67] Giovannelli, F., Sabau-Graziati, L. (eds.): 2014, Proc. Frascati Workshops on *Multifrequency Behaviour of High Energy Cosmic Sources*, Acta Polytechnica (in preparation).

[68] Giovannelli, F., Sabau-Graziati, L.: 2008, ChJA&AS 8, 1.

[69] Giovannelli, F., Gualandi, R., Sabau-Graziati, L.: 2010, ATEL No. 2497.

[70] Giovannelli, F., Sabau-Graziati, L.: 2010b, in *Multifrequency Behaviour of High Energy Cosmic Sources*, F. Giovannelli & L. Sabau-Graziati (eds.), Mem. SAIt 81 N. 1, 18.

[71] Giovannelli, F., Sabau-Graziati, L.: 2011, Acta Polyt. 51 N. 2, 21.

[72] Giovannelli, F., Sabau-Graziati, L.: 2012b, in *Multifrequency Behaviour of High Energy Cosmic Sources*, F. Giovannelli & L. Sabau-Graziati (eds.), Mem. SAIt 83 N. 1, 17.

[73] Giovannelli, F., Sabau-Graziati, L.: 2012c, in *The Golden Age of Cataclysmic Variables and Related Objects*, F. Giovannelli & L. Sabau-Graziati (eds.), Mem. SAIt 83 N. 2, 440.

[74] Giovannelli, F., Bisnovatyi-Kogan, G.S., Klepnev, A.S.: 2013, arXiv: 1305.5149v1; A&A, in press.

[75] Greco, M. (ed.): 2009, 2010, *Le Rencontres de Physique de la Vallée d'Aoste: Results and Perspectives in Particle Physics*, Frascati Phys. Ser. Vol. L, Vol. LI.

[76] Greiner, J. et al.: 2009, ApJ 693, 1610. doi:10.1088/0004-637X/693/2/1610

[77] Gustavino, C.: 2007, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 93, 191.

[78] Gustavino, C.: 2009, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 98, 77.

[79] Gustavino, C.: 2011, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 103, 657.

[80] Hess, V.F.: 1912, Physik Zh. 13, 1084.

[81] van den Heuvel, E.P.J.: 2009, Ap&SS Library 359, 125.

[82] Hillas, A.M., Johnson, A.P.: 1990, *Proc. 21st Intern. Cosmic Ray Conf. (Adelaide)* 4, 19.

[83] Hurley, K.: 2008, ChJA&AS 8, 202.

[84] Izzo, L. et al.: 2010, J. Korean Phys. Soc. 57, No. 3, 551.

[85] Johnstone, Wm.R.: 2005, http://www.johnstonsarchive.net/relativity/binpulstable.html

[86] Kappes, A., Hinton, J., Stegman, C., Aharonian, F.A.: 2007, ApJ 656, 870. doi:10.1086/508936

[87] Kuiper, L.: 2007, Talk presented at the Frascati Workshop on *Multifrquency Behaviour of High Energy Cosmic Sources*.

[88] LaRosa, T.N., Kassim, N.E., Lazio, T.J.W., Hyman, S.D.: 2000, AJ 119, 207.

[89] Lenain, J.-P.: 2010, in *Multifrequency Behaviour of High Energy Cosmic Sources*, F. Giovannelli & L. Sabau-Graziati (eds.), Mem. SAIt 81 N. 1, 362.

[90] Lipunov, V.M.: 1995, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Bologna, Italy 47, 61.

[91] Martinez, M.: 2007, Ap&SS 309, 477. doi:10.1007/s10509-007-9445-4

[92] Mather, J.C. et al.: 1994, ApJ 420, 439.

[93] Mereghetti, S., Stella, L.: 1995, ApJL 442, L17.

[94] Meszaros, P., Rees, M.J.: 1992, ApJ 397, 570.

[95] Mezger, P.G., Duschl, W.J., Zylka, R.: 1996, A&A Rev. 7, 289.

[96] Mezzetto, M.: 2011, Journal of Physics: Conference Series 335, 012005. doi:10.1088/1742-6596/335/1/012005

[97] Morselli, A.: 2007, in *High Energy Physics ICHEP '06*, Y. Sissakian, G. Kozlov & E. Kolganova (eds.), World Sci. Pub. Co., p. 222. doi:10.1142/9789812790873_0025

[98] Ouchi, M. et al.: 2010, ApJ 723, 869. doi:10.1088/0004-637X/723/1/869

[99] Palanque-Delabrouille, N.: 2003, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 85, 131.

[100] van Paradijs, J.: 1998, in *The Many Faces of Neutron Stars*, R. Buccheri, J. van Paradijs & and M.A. Alpar (eds.), Kluwer Academic Publ., Dordrecht, Holland, p. 279.

[101] van Paradijs, J., Taam, R.E., van den Heuvel, E.P.J.: 1995, A&A 299, L41.

[102] Paredes, J.M., Persic, M.: 2010, in *Multifrequency Behaviour of High Energy Cosmic Sources*, F. Giovannelli & L. Sabau-Graziati (eds.), Mem. SAIt 81 N. 1, 204.

[103] Piran, T.: 1999, Phys. Rep. 314, 575.

[104] Piran, T.: 2010, arXiv1005.3311.

[105] Rahoui, F., Chaty, S., Lagage, P.-O, Pantin, E.: 2008, A&A 484, 801.

[106] Ressel, M.T., Turner, M.S.: 1990, Comm. Astrophys. 14, 323.

[107] Ruffini, R. et al.: 2003, AIP Conf. Proc. 668, 16. doi:10.1063/1.1587092

[108] Schroedter, M.: 2005, ApJ 628, 617. doi:10.1086/431173

[109] Srianand, R., Petitjean, P., Ledoux, C.: 2000, Nature 408, 931. doi:10.1038/35050020

[110] Straessner, A. (on behalf of the ATLAS Collaboration): 2011, in *Frontier Objects in Astrophysics and Particle Physics*, F. Giovannelli & G. Mannocchi (eds.), Italian Physical Society, Ed. Compositori, Bologna, Italy, 103, 43.

[111] Tanvir, N.R. et al.: 2009, Nature 461, 1254. doi:10.1038/nature08459

[112] Taylor, A.M. et al.: 2008, in *High Energy Gamma-Ray Astronomy*, AIP Conf. Proc. 1085, 384. doi:10.1063/1.3076687

[113] Tozzi, P. et al.: 2003, ApJ 593, 705. doi:10.1086/376731

[114] Wang, F.Y., Dai, Z.G.: 2009, MNRAS 400, 10.

[115] Xu, X.W. (IceCube Collaboration): 2008, N. Phys. B 175-176, 401.